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DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

VAN H. MANNING, DIRECTOR

HAZARDS IN HANDLING GASOLINE

BY

GEORGE A. BURRELL

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CONTENTS.

Page.
Introduction 5
Miscellaneous hazards in the use of gasoline 5
Detailed precautions concerning the handling of gasoline 6
A few terse directions 7
Extinguishing burning liquids 7
    Use of foam or a frothy liquid mixture as an extinguisher 8
Relation of properties of gasoline and gasoline vapor to inflammability 9
    Source of gasoline 9
    Action of gasoline vapor in air 9
    Comparison of inflammability of gasoline and of gasoline vapor 10
    Explosive range of mixtures of gasoline vapor and air 10
    Résumé 11
Publications on petroleum technology 12

HAZARDS IN HANDLING GASOLINE.

By George A. Burrell.

INTRODUCTION.

With the increasing use of gasoline and other liquid fuels that are dangerous because of their ready inflammability there is each year an increasing number of accidents that cause loss of life and great damage to property. In connection with investigations regarding safety and efficiency in the use of petroleum and its products, the Bureau of Mines has made numerous tests of gasoline and kerosene. This report discusses hazards that may result from handling the liquids mentioned, and outlines precautions to be observed in handling them.

A recent tabulation by K. G. Martin of the fire prevention bureau of New York City shows that during 1913 in the United States 1,040 persons were burned to death and 3,120 persons injured (a weekly average of 20 persons killed and 60 persons injured) on account of gasoline fires.

A study[a] of 1,000 fires showed that 77.1 per cent were due to gasoline, naphtha, and benzol; 53 per cent were due to open flames, matches, and static or frictional electricity.

In 1912, from transportation of gasoline on railroads alone, there resulted a property loss due to fires of $31,215, and in 1913 the loss from that source had increased to $117,697.[b]

MISCELLANEOUS HAZARDS IN THE USE OF GASOLINE.

In gasoline-lighting systems, there are many hazards that can be introduced by faulty design and construction of apparatus. Among these are corrodible material, improperly made joints, and valves of poor design.

Many fires originate from the cleaning of silks with gasoline, the violent rubbing of the silk generating static electricity which produces a spark that ignites the vapor.

Many jobbing tailors cause fires by using gasoline in an open vessel and smoking a cigarette or cigar at the same time.

A dangerous practice, common in many garages, is the cleaning of automobile parts with gasoline from an open can. Employees find it easy to clean grease and oil from the motor and other parts with a brush saturated with gasoline, and the gasoline is readily ignited by a spark. Such a spark may be caused by striking two pieces of metal together, by the ignition system on the automobile when the starting crank is turned, and in other ways. In one instance a nut that stuck was struck with a wrench, causing a spark. The car was instantly enveloped in flame.

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[a] Nat. Fire Prot. Assn. Quart., vol. 7, July, 1913, p. 73.

[b] Proc. Am. Railway Assn., May 20, 1914, p. 480.

Oily waste should at all times be placed in a safe receptacle to avoid the danger of spontaneous combustion. Oily waste will decay, smolder, and in time burst into flame. Sawdust when soaked with oil drippings will do the same thing, and its use should be forbidden. Sand is a safe material to use as an absorbent of oil.

Another source of fires is the use of kerosene in lighting fires in the ordinary cooking or heating stove. Kerosene should never be poured in a stove in which there is a spark of fire; neither should it be used in a stove in which the fire is out, but in which parts of the stove are still warm. Neither should kerosene lamps be filled while lighted, a practice that is widely prevalent in country districts. Kerosene lamps with metal oil wells are safer than and are preferable to lamps with glass fonts.

DETAILED PRECAUTIONS CONCERNING THE HANDLING OF GASOLINE.

In establishments where benzine, gasoline, naphtha, and other inflammable liquids are used, care should be taken to see that the smallest practicable quantities are used, and that the liquids are handled in an approved manner. No open light or flame of any kind, nor any machine or belt capable of producing a spark should be allowed in the room where the gasoline is being used. All shafting and machines with belts that are liable to cause a static electric spark should be well grounded.

Only incandescent electric lights should be used, and these should be provided with guards to prevent their being smashed.

All electric switches, fuses, etc., should be outside the room.

Danger signs should be posted on all doors opening into the room, warning against the carrying of open lights of any kind inside.

When large quantities of the inflammable liquids mentioned are used the main supply should be stored in a metal tank buried underground and a safe distance from buildings. The working supply should be pumped into the buildings as needed, and the system so arranged that when the pump is stopped all liquid in the pipes will flow back into the supply tank. When it is not possible to use a pump and a buried tank the main supply should be stored outside and well away from other buildings, under lock and key. Only small quantities of working supplies should be taken into the building, closed metal cans, preferably safety cans, being used as containers.

When the use of an open pan is necessary the opening should be as small as possible and a cover should be provided. The cover should be put on whenever the pan is not in use.

Signs should be posted prohibiting an open flame near the place of storage or near a pump or other handling apparatus. The signs should explain the danger involved and give instructions for safe methods of operation.

Empty gasoline barrels should be stored with bungholes down, in safe places in the open air.

Rooms in which explosive or dangerous gases or vapors are used or generated should be safely inclosed, and should be provided with an improved system of ventilation.

Gasoline vapor is heavier than air, and a suction fan should be used to insure proper ventilation.

Joints in tanks, pipes, conveyors, etc., used for storage of explosive liquids, gases, or vapors should be kept tight.

Before work is done on vessels, pipes, etc., sufficient time should be given to allow gas to escape.

Special care should be exercised before work requiring the use of heat or flame is done. Apparatus that has contained explosive gas should be filled with water or steam to force out the gas.

A FEW TERSE DIRECTIONS.

Don't spill gasoline.

Don't fill the tank of the liquid-fuel stove full.

Don't use a liquid-fuel stove that leaks.

Don't fill a gasoline stove in a closed room. Have plenty of ventilation to carry the vapor out of the room.

Don't use gasoline or naphtha for washing the hands.

EXTINGUISHING BURNING LIQUIDS.

There are two principal methods of extinguishing burning liquids, as follows:

1. To form a blanket of gas or solid material over the burning liquid and cut off the air (oxygen) supply.
2. To dilute the burning liquid with a noninflammable extinguishing agent that will mix with it.

Water may be used for extinguishing burning liquids, such as denatured alcohol, wood alcohol, and acetone, that are miscible with it. If such a liquid as gasoline, which is not miscible with water, catches fire, the application of water produces little or no effect except to spread the burning liquid, and thus scatter the fire over a larger area. However, the application of a large quantity of water to a small quantity of burning oil, by its cooling effect, may aid in extinguishing the fire.

Of materials used to form a blanket of gas or solid material over burning liquid, thus cutting off the oxygen supply, several are in common use. These include sawdust, sand, carbon tetrachloride, and the so-called foam or frothy mixtures.

The efficiency of sawdust is due to its floating for a time on the liquid and excluding the oxygen of the air. Sawdust itself is not easily ignitible, and when it does ignite burns without flame. The character of the sawdust and its moisture content is of little or no importance. It may be well handled for extinguishing small fires, when just started, by means of long-handled wooden shovels.

Sand probably serves about as well as sawdust for extinguishing fires on the ground, but is heavier and more awkward to handle. When thrown on a burning tank it sinks, whereas sawdust floats.

Carbon tetrachloride, the basis of various chemical fire extinguishers, if thrown on a fire forms a heavy noninflammable vapor over the liquid, and mixes readily with oils, waxes, japan, etc. The vapor is about five times as heavy as air. Much of the carbon tetrachloride contains impurities that give it a bad odor, but when pure its specific gravity is 1.632 at 32° F. When thrown on a fire, it produces black smoke, the hue of which is caused by unconsumed particles of carbon. Pungent gases are also produced, probably hydrochloric acid gas and small volumes of chlorine gas. Although the fumes are pungent, brief exposure to them does not cause permanent injury.

The efficacy of carbon tetrachloride depends largely on the skill of the user. If liquid in a tank is on fire, the height of the liquid is important. When the liquid is low, the sides of the tank form a wall which retains the vapor, but when a tank is nearly full of a highly volatile liquid like gasoline, only the most skilled operator can extinguish the fire.

For smothering some small fires of burning gasoline an ordinary blanket may be used.

USE OF FOAM OR A FROTHY LIQUID MIXTURE AS AN EXTINGUISHER.

Installations embracing the use of foam or frothy liquid mixtures to extinguish fires in large gasoline storage tanks originated in Germany. For such an extinguisher two liquids are caused to mix in a tank, whereupon foam is produced. The tank is made air-tight and sufficiently strong to permit the foam to be forced out under pressure of a gas (carbon dioxide) simultaneously generated. The frothy mixture owes its efficacy to its blanketing action in excluding air (oxygen) from the fire. It is stiff and shrinks only slightly in volume even after half an hour. In one installation water, bicarbonate of soda, and soap bark are used in one tank, and acid in another tank. A fusible link, which will melt at 212° F., releases a hammer, which breaks the glass tank containing the acid. The released acid is led through two perforated pipes into the solution, producing a violent ebullition of foam, which finds its way into the tank of burning oil.

The National Fire Protection Association has experimented with this and other methods of extinguishing fire. These experiments show the method to be promising.

In some large plants gasoline is continually stored under the pressure of noninflammable gas, as nitrogen or carbon dioxide. In other plants it is stored in a tank, which is always kept filled, no air being admitted at any time. The tank may be filled with all gasoline or part gasoline and part water, water being pumped into the tank to force out the gasoline, when desired. The water may be drained off when more gasoline is to be added to the tank.

RELATION OF PROPERTIES OF GASOLINE AND GASOLINE VAPOR TO INFLAMMABILITY.

SOURCE OF GASOLINE.

Gasoline is a product obtained by distilling crude petroleum, and the different grades used for various purposes differ somewhat in chemical and physical properties. Some grades of gasoline, particularly the better grades used to drive automobiles, are much more hazardous to handle than are others. They mix with air in larger proportions and pass into the vapor form (evaporate) more rapidly, and hence more quickly render a given volume of air explosive than do the heavier grades, such as are used for cleaning purposes and for fuel in the engines of some motor trucks and other large internal-combustion engines.

ACTION OF GASOLINE VAPOR IN AIR.

Gasoline vapor mingles with air in the same manner that water vapor does. At any particular temperature a definite proportion of water vapor will be found in the atmosphere if it has become completely saturated, a condition that seldom exists. Usually a limited supply of water has been given off into the air, and the atmosphere is spoken of as having a certain relative humidity, meaning that the saturation is incomplete or that more water vapor could exist in the air were a source of moisture available. In a similar manner gasoline vapor mixes with air. The amount of vapor carried will depend on the temperature of the air and the readiness with which the vapor can be obtained.

If gasoline is exposed to the air of a room and for a long enough time, the air will contain at a certain temperature a fixed proportion of gasoline vapor, differing for different grades of gasoline, that can not be exceeded. The author has worked out the values for four different grades. The results for a temperature of 17.5° C. (63.5° F.) are shown in the following table:

Proportions of different grades of gasoline vapor that air will carry at a temperature of 17.5° C.

Grade of gasoline.	Proportion of gasoline vapor (per cent).
Cleaner's naphtha	5.0
64° B. gasoline	11.0
69° B. gasoline	15.0
73° B. gasoline	28.0

It will be noticed that air will hold almost six times as much vapor from the lighter gasoline as from the heavier cleaner's naphtha. If the lighter and better grades of gasoline are heated, their vapors, when a light is applied, also flash and burn at lower temperatures than do the heavier grades. This difference does not mean that some gasoline is a dangerous inflammable liquid and some is not. All grades are classed as highly inflammable and dangerous liquids.

COMPARISON OF INFLAMMABILITY OF GASOLINE AND OF GASOLINE VAPOR.

If one takes the cover off a full pail of tightly inclosed gasoline and applies a match to the surface, the gasoline will flare up and burn as long as the gasoline lasts. On the other hand, if one puts a few drops of gasoline in a small tightly inclosed pail, waits a few minutes, and then introduces a flame or an electrical spark a violent explosion will most likely result. In the first case the vapor burns as fast as it comes from the gasoline, and mixes with the oxygen of the air. In the second case the oil vaporizes in the pail and mixes uniformly with the air therein to form an explosive mixture and upon ignition explodes. Consequently, when one hears of a disastrous gasoline explosion one may be sure that the explosion resulted from the mixing of the vapor from the gasoline with air in the proportions necessary to form an explosive mixture.

One gallon of gasoline when entirely vaporized produces about 32 cubic feet of vapor. If a lighted match could be applied to pure gasoline vapor in the absence of air no fire or explosion would result. Gasoline liquid or vapor, like any other combustible material, needs the oxygen of the air in order to burn.

EXPLOSIVE RANGE OF MIXTURES OF GASOLINE VAPOR AND AIR.

It is fortunate that gasoline vapor, like other gases and vapors, needs a certain proportion of air before an explosion can take place. The author found that in 100 parts by volume of air and gasoline, an explosion will not take place if there is less than 1.4 parts of gasoline vapor or more than 6 parts.[a] In other words, the explosive range is between 1.4 and about 6 per cent of vapor. Flashes of flame will appear in mixtures containing considerably smaller and larger proportions of vapor, and considerable pressure will be developed, but propagation through the mixture will not take place.

Although the range of explosibility mentioned is narrow as compared to that of many other mixtures of combustible gases and air, yet the proportion of gasoline vapor representing the lower limit is small, and indicates the great importance of not allowing even a little gasoline to be exposed in a room, because of the small quantity of vapor needed to make an explosive mixture with all the air in the room. If 1 gallon of gasoline is allowed to change completely into vapor simply by exposing it to the room air, and if the room is gas-tight, the 1 gallon can render explosive 2,100 cubic feet of air, the amount contained in a room measuring 21 by 10 by 10 feet.

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[a] Burrell, G. A., and Boyd, H. T., Inflammability of mixtures of gasoline vapor and air: Technical Paper 115, Bureau of Mines, 1915, p. 10.

In the actual use of gasoline such conditions seldom exist. However, an assumed case may be that of a person filling an open pail from a larger tank or using gasoline for cleaning. When the pail is first filled with the gasoline, a small volume of pure gasoline vapor forms over the surface of the gasoline. Just above this layer of pure gasoline vapor is a mixture of vapor and air; at some point there will be an explosive proportion, and farther away from the pail there will be a small proportion of vapor, and finally still farther away no vapor at all, but pure air. However, all the time the user of the gasoline is at work, the vapor keeps forming, from both the gasoline in the pail and that applied to the object being cleaned, rendering more and more air inflammable or explosive, until finally there will exist a dangerous atmosphere that may completely surround him, so that a chance ignition will envelope him in flames and perhaps cause great damage to property. Ignition of the gasoline vapor may take place even some distance from the gasoline in a room adjoining the room in which the person works. As the gasoline evaporates, and more and more vapor is given off, it mixes with air farther and farther from the gasoline and, if the evaporation lasts long enough, may travel to an adjoining room, where it may be ignited. On ignition a sharp flash will travel back through the adjoining room to the room where the gasoline is.

RÉSUMÉ.

At ordinary temperatures air will hold about 5 to 28 per cent of gasoline vapor. As gasoline vapor is about three times as heavy as air, in a room containing a mixture of the vapor with air the vapor is found in largest proportion near the floor.

The limits of explosibility of mixtures of gasoline vapor and air are between about 1.4 and 6 per cent of gasoline vapor, although dangerous flashes may be produced with mixtures containing less and more than these proportions. In other words, there is needed only a small proportion of gasoline vapor to render air explosive—1.4 cubic feet of the vapor to 97.5 cubic feet of air. One gallon of gasoline can under ideal conditions render 2,100 cubic feet of air explosive.

A dangerous feature of gasoline vapor is that it may travel a considerable distance from the gasoline and there be ignited, the flash traveling back to the container of the liquid and causing a roaring fire in a few seconds.

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BULLETIN 88. The condensation of gasoline from natural gas, by G. A. Burrell, F. M. Seibert, and G. G. Oberfell. 1915. 106 pp., 6 pls., 18 figs.

TECHNICAL PAPER 3. Specifications for the purchase of fuel oil for the Government, with directions for sampling oil and natural gas, by I. C. Allen. 1911. 13 pp.

TECHNICAL PAPER 10. Liquefied products from natural gas, their properties and uses, by I. C. Allen and G. A. Burrell. 1912. 23 pp.

TECHNICAL PAPER 25. Methods for the determination of water in petroleum and its products, by I. C. Allen and W. A. Jacobs. 1912. 13 pp., 2 figs.

TECHNICAL PAPER 32. The cementing process of excluding water from oil wells as practiced in California, by Ralph Arnold and V. R. Garfias. 1913. 12 pp., 1 fig.

TECHNICAL PAPER 37. Heavy oil as fuel for internal-combustion engines, by I. C. Allen. 1913. 36 pp.

TECHNICAL PAPER 38. Wastes in the production and utilization of natural gas, and means for their prevention, by Ralph Arnold and F. G. Clapp. 1913. 29 pp.

TECHNICAL PAPER 42. The prevention of waste of oil and gas from flowing wells in California, with a discussion of special methods used by J. A. Pollard, by Ralph Arnold and V. R. Garfias. 1913. 15 pp., 2 pls., 4 figs.

TECHNICAL PAPER 45. Waste of oil and gas in the Mid-Continent fields, by R. S. Blatchley. 1914. 54 pp., 2 pls., 15 figs.

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TECHNICAL PAPER 66. Mud-laden fluid applied to well drilling, by J. A. Pollard and A. G. Heggem. 1914. 21 pp., 12 figs.

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TECHNICAL PAPER 74. Physical and chemical properties of the petroleums of California, by I. C. Allen, W. A. Jacobs, A. S. Crossfield, and R. R. Matthews. 1914. 38 pp., 1 fig.

TECHNICAL PAPER 79. Electric lights for oil and gas wells, by H. H. Clark. 1914. 8 pp.

TECHNICAL PAPER 89. Coal-tar products, and the possibility of increasing their manufacture in the United States, by H. C. Porter, with a chapter on coal-tar products used in explosives, by C. G. Storm. 1915. 21 pp.

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Technical Paper 127 a, (Revised ed.)

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

HAZARDS IN HANDLING GASOLINE

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GEORGE A. BURRELL

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CONTENTS.

Page.

Introduction 3

Relation of properties of gasoline and of gasoline vapor to inflammability 4

  Action of gasoline vapor in air 5

Precautions in handling gasoline 7

Causes of recent gasoline fires 9

Asphyxiation by exhaust gases of automobile engines 10

Gasoline fires caused by filtering gasoline through chamois skin 11

Extinguishing liquid fires 12

Use of foam or a frothy mixture 13

Summary 14

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HAZARDS IN HANDLING GASOLINE.

By George A. Burrell.

INTRODUCTION.

With the increasing use of gasoline and similar liquids that are dangerous because of ready inflammability there is each year an increase in the number of accidents that result fatally and cause, all told, a tremendous property loss. The purpose of this paper is to point out the hazards in handling gasoline and the precautions by which these hazards may be avoided or reduced to a minimum.

A tabulation made by K. G. Martin, of the fire-prevention bureau of New York City, shows that during 1913 in the United States 1,040 persons were burned to death and 3,120 persons injured (a weekly average of 20 persons killed and 60 persons injured) on account of gasoline fires.

A study[a] of 1,000 fires from volatile liquids showed that 77.1 per cent were due to gasoline, benzol, and naphtha. The causes of these 771 fires are given as follows:

Causes of fires from volatile liquids.

Cause of fire.	Number of fires.
Open flames from gas jets	52
Open flames from gas stoves	13
Open flames from gas-heated Japan ovens	6
Open flames from gas heating stoves	4
Open flames from gas heating soldering irons	3
Open flames from various machines	4
Open flames from kerosene oil lamps	20
Open flames from lanterns used for lighting	18
Open flames from lanterns used by watchmen	17
Open flames from alcohol lamps	4
Open flames from candle lights	5
Open flames from automobile headlights	2
Open flames from open-flame torches	13
Open flames from heating systems	21
From open fires	5
From miscellaneous open flames	7
Use of matches	116

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[a] Robinson, J. A. Nat. Fire Prot. Assn. Quart., vol. 7, July, 1913, p. 7.

Cause of fire.	Number of fires.
Electric sparks	54
Flying sparks	39
Static or frictional electricity	99
Miscellaneous frictional heat	2
Contributory heat	19
Gasoline gas systems	25
Back-firing at automobile carburetor	22
Smoking	28
Automobile engines cleaned with benzine	7
Gasoline mistaken for kerosene	6
Gasoline torches	20
Explosions from uncertain or unknown causes	41
Miscellaneous	8
Causes undetermined, unreported, or unknown	91

In 1912 the transportation of gasoline on railroads alone resulted in a property loss from fires of $31,215; in 1913 the loss was nearly four times as large, $117,697.[a]

Measured by loss of life, number of persons injured, and extent of damage to property, one of the most disastrous accidents from the transportation of dangerous articles occurred at Ardmore, Okla., September 27, 1915. Forty-three persons were killed, and the number injured is variously reported at 150 to 300. The property loss was placed at $500,000 to $1,000,000.

A tank car was loaded with gasoline to within 1 inch of the dome, instead of a vacant space of about 2 per cent (205 gallons in this case) being left as required by the Interstate Commerce Commission regulations. At noon on the day of the explosion the internal expansion or pressure of the contents (due to the high temperature of the atmosphere) of the car had raised the safety valve, and gas and liquid were escaping freely. At 2.15 p. m. a man unscrewed the dome cap without first reducing the pressure by cooling the surface of the tank with water. When the cap had been removed, large quantities of gasoline were forced out of the tank car, and as the man descended to the ground the explosion occurred.

The explosion was probably caused by the escaping gasoline vapors being blown either to a fire in an asphaltum plant 330 feet from the car or to a lighted switch lamp, where they became ignited and flashed back to the car.

RELATION OF PROPERTIES OF GASOLINE AND OF GASOLINE VAPOR TO INFLAMMABILITY.

Gasoline is a product obtained by distilling crude petroleum, and the different grades used for various purposes differ somewhat in chemical and physical properties. Some grades, particularly the better grades used to drive automobiles, are much more hazardous

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[a] Proc. Am. Ry. Assn., May 20, 1914, p. 480.

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to handle than others. They mix with air in larger proportions and pass into the vapor form (evaporate) more rapidly, and hence more quickly render a given volume of air explosive than do the heavier grades, such as are used for cleaning and for fuel in the engines of motor trucks and other internal-combustion engines.

ACTION OF GASOLINE VAPOR IN AIR.

Gasoline vapor mingles with air in the same manner that water vapor does. At any particular temperature a definite proportion of water vapor will be found in the atmosphere if the latter is completely saturated, a condition that seldom exists. Usually the amount of water vapor is less, and the atmosphere is said to have a certain relative humidity, meaning that the saturation is incomplete and that more water vapor can exist in the air.

In a similar manner gasoline vapor mixes with air. The amount of vapor carried will depend on the temperature of the air and on other conditions. If gasoline is exposed to the air of a room for a long enough time, the air will contain at a certain temperature a fixed proportion of gasoline vapor that can not be exceeded. For different grades of gasoline this value will differ. The author has worked out the values for four different grades. The results for a temperature of 17.5° C. (63.5° F.) are shown in the following table.[a]

Proportions of different grades of gasoline vapor that air will carry at a temperature of 17.5° C.

Grade of gasoline.	Percentage of gasoline vapor.
Cleaner's naphtha	5.0
64° B. gasoline	11.0
69° B. gasoline	15.0
73° B. gasoline	28.0

It will be noticed that air will hold almost six times as much of the vapor from the lighter gasoline as of the vapor from the heavier cleaner's naphtha. When these lighter and better grades of gasoline are heated, their vapors, when a light is applied, flash and burn at lower temperatures than do the vapors of the heavier grades. This difference does not imply that some gasoline is dangerously inflammable and that some is not. All grades are classed as highly inflammable and dangerous liquids. If one takes the cover off a full pail of tightly inclosed gasoline and applies a match to the surface, the gasoline flares up and continues to burn as long as the gasoline lasts. On the other hand, if one puts a few drops of gasoline into a small tightly inclosed pail, waits a few minutes, and then introduces a flame or an electrical spark into the pail, a violent explosion will most likely result. In the first experiment the vapor burned as fast as it came from the gasoline and mixed with the oxygen of the air. In the second experiment the oil vaporized in the pail and mixed uniformly with the air therein to form an explosive mixture, and upon ignition exploded. In other words, when one hears or reads of a disastrous gasoline explosion, one may be sure that the explosion resulted from the mixing of vapor from the gasoline with air in the proportions necessary to form an explosive mixture. If a match or other means of ignition could be applied to pure gasoline vapor no fire or explosion would result, owing to the absence of air. For the combustion of gasoline, liquid or vapor, as is true of all combustible materials, oxygen is required.

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[a] Burrell, G. A., and Boyd, H. T., Quantity of gasoline necessary to produce explosive conditions in sewers: Tech. Paper 117, Bureau of Mines, 1916, p. 15.

As with other gases and vapors, it is fortunate that before an explosion of gasoline vapor can occur, the exact explosive proportion of air must be present. The author found that in 100 parts by volume of air and gasoline, an explosion will not take place if there is less than 1½ or more than 6 parts of gasoline vapor.[a] In other words, the explosive range is between 1½ and about 6 per cent of gasoline vapor. Although this range of explosibility is narrow as compared with that of many other mixtures of combustible gases and air, yet the lower limit involves a very small proportion of gasoline vapor, indicating the great importance of not allowing even a little gasoline to be exposed in a room. If 1 gallon of gasoline that is sufficiently volatile were allowed to change completely into vapor simply by being exposed to the air in a room, and if the room were gas tight, this 1 gallon could make explosive about 2,100 cubic feet of air, the amount contained in a room measuring 10 by 10 by 21 feet.

In the actual use of gasoline such a condition is not found. Imagine that a person is filling an open pail from a larger tank, or is sponging a dress with gasoline from an open can. When the pail is first filled with the gasoline, a small amount of pure gasoline vapor is given off just over the surface of the gasoline. Just above this layer of pure gasoline vapor is a mixture of gasoline vapor and air, which at some point contains an explosive proportion of the two constituents. Farther away from the pail there will be a very small proportion of vapor, and still farther away no vapor at all, but just pure air. However, all the time the user of the gasoline is at work the vapor keeps forming, both from the gasoline in the pail and from the sponge and the dress goods, rendering more and more air inflammable or explosive, until finally there exists a dangerous atmosphere, perhaps completely surrounding him, and needing only a source of ignition to envelope him in flames. Ignition of the gasoline vapor may take place even in a room adjoining the room in which the operator is working, and some distance from the gasoline. As the gasoline evaporates, more and more vapor is given off which mixes with air farther and farther from the gasoline and may, if the evaporation lasts long enough, travel to an adjoining room and perhaps be ignited there. Upon ignition a sharp flash will travel back through the room to the gasoline. Gasoline vapor is about three times as heavy as air, and in traveling from the gasoline will be present in greater proportion near the floor.

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[a] Burrell, G. A., and Boyd, H. T., The limits of inflammability of mixtures of gasoline vapor and air: Tech. Paper 115, Bureau of Mines, 1915, pp. 15–16.

PRECAUTIONS IN HANDLING GASOLINE.

In establishments where benzine, gasoline, naphtha, and other inflammable liquids are used, care should be taken to see that only small quantities are used, and that the liquids are handled in an approved manner. No open lights, nor flames, nor any moving machine or belt capable of producing a spark of any kind should be allowed in a room where the liquids are being used. In any building where inflammable liquids are used, all shafting and machines with belts that are liable to cause a static electric spark should be well grounded.

Only incandescent electric lights should be used, and these should be provided with guards to prevent the bulbs being smashed.

All electric switches and fuses should be outside the room.

Danger signs, giving warning against the carrying of open lights of any kind, should be posted on all doors opening into the room where the inflammable liquids are used.

If large quantities of these substances are used, the main supply should be stored in a metal tank buried at least 2 feet under ground and at least 30 feet from buildings. The working supply should be pumped into the buildings as needed, and the system should be so arranged that when the pump is stopped the supply pipes will remain full of the liquid. Where it is not possible to use a pump and a buried tank, the main supply should be stored outside and well away from other buildings, under lock and key. Working supplies should be taken into the building in closed metal cans only, of not more than 10-gallon capacity, and safety cans should be used whenever possible.

When the use of open pans is necessary, the opening should be as small as possible, and a cover should be provided.

Signs should be posted prohibiting an open flame near the place of storage, or near a pump, or other handling apparatus. These signs should state the danger involved and the precautions necessary.

Empty gasoline barrels should be stored with bung holes down, in safe places in the open air.

Rooms in which explosive or dangerous gases or vapors are used or generated should be separated and provided with an approved system of ventilation, preferably by two windows on opposite sides of the room.

If the gas or vapor is lighter than air, hoods and vents without suction fans may be enough, but if it is heavier than air a suction fan on a down-draft system of ventilation should be used.

Joints in tanks, pipes, conveyers, etc., used for the storage of explosive liquids, gases, or vapors should be kept tight.

Before work is done on recently emptied vessels, pipes, etc., sufficient time should be given to allow gas to escape.

Special care should be exercised before doing work that requires the use of heat or flame. Apparatus that has contained explosive gas should be filled with water or steam to force out the gas.

In gasoline lighting systems, there are many hazards that can be introduced by faulty design and construction of apparatus. Among these are corrodable material, improperly made joints, valves of poor design, and gasoline containing acid that has not been neutralized in the refinery and so may attack the pipes, etc.

Fires originate in cleaning silks, violent rubbing of the silk generating static electricity that produces a spark and a consequent explosion.

Jobbing tailors cause fires by trying to do two things at once—use gasoline in an open vessel and smoke a cigarette or cigar at the same time. In this connection, the author was unable to light gasoline vapor with the glowing end of a cigar or a cigarette, although grades of gasoline tested included some light casing-head gasoline and, by suction, the lighted end of the cigar or cigarette was made to glow strongly. The danger is not from the cigar or cigarette itself, but from the match used in lighting or relighting it.

A dangerous practice common in many garages is to use gasoline to clean an automobile standing over a washing rack, the gasoline accumulating on top of the water in the rack. Then too, the gasoline is often used from an open vessel. Employees find it easy to clean grease and oil from the motor and other parts with a brush saturated with gasoline. The resulting gasoline vapor is readily ignited in many different ways.

Gasoline should not be put near places where sparks will fall. Gasoline fires have been caused by sparks produced by metal striking against metal, from emery wheels, from the clash of metal on concrete floors, from nails in shoes, from burning material, from a forge, from a steam hammer, from a saw, and from other causes.

Oily waste should at all times be placed in a safe receptacle on account of spontaneous combustion. Oily waste absorbs oxygen, heats, and in time bursts into flame. Sawdust when soaked with oil drippings will do the same thing and the use of sawdust for absorbing oil should be forbidden. Sand is a safe commodity that will absorb oil.

In homes, spontaneous combustion caused by oily rags and cloths kept in closets is a frequent source of fire. Oil rags are used in rubbing floors, furniture, ranges, and miscellaneous metal work. The recent widely extended use of oily mops has increased this danger to an appreciable extent on account of the comparatively large amount of oil that these mops hold. Any oil on and in the fibers of the oily rags and mops oxidizes rapidly, and, in the confined spaces in which they are kept, generates enough heat to ignite the particles of dust and dirt with which the oil is covered. The best way to obviate the danger of spontaneous combustion is to keep such rags and mops separated as much as possible, to remove any excess of oil before putting them away, and to secure ventilation of the place where they are kept by keeping the door ajar or by boring holes in the door or sides of the closet. These precautions will lessen the chances of heat being generated and the supply of fresh air will keep the temperature down to a point where combustion is not possible. Even then the rags should be kept in a galvanized-iron pail.

Another source of occasional fires is caused by the use of kerosene in lighting fires in the ordinary cooking or heating stove. Kerosene should never be poured in a stove in which there is a spark of fire; neither should it be used in a stove in which the fire is out but still warm. Kerosene should not be used for starting fires; neither should kerosene lamps be filled while lit, although this is a prevalent practice throughout rural districts. Kerosene lamps with metal oil wells are safer, and preferred to the ordinary country lamps with glass fonts. The man who handles oil can not be too careful and should help to spread this propaganda to the public.

CAUSES OF RECENT GASOLINE FIRES.

A few concrete instances of fires caused by gasoline are cited below.

A short circuit in the wiring of a portable electric light caused a spark that ignited gasoline vapors in a shed used for storing automobiles.

While automobiles were being cleaned in a machine shop, the bulb of a lighted portable incandescent lamp was accidentally broken, igniting vapors which flashed back into the can of gasoline.

In a shoe factory where a boy was cleaning a brush wheel with benzine, the vapor from the benzine was ignited by a gas light.

A workman was washing his hands with a silk cloth saturated with benzine. Rubbing the cloth generated static electricity which ignited the vapor. In trying to shake the burning benzine from his hands the workman scattered the fire and ignited some benzine in a quart tin pail on a near-by bench.

While one employee was cleaning some small parts of machinery with benzine another employee passed near him with a lighted torch that ignited the vapor from the benzine.

A kerosene stove was filled with gasoline by mistake. When the stove was lighted it flared up and the blaze spread to a table on which was paper.

Fire started from spontaneous combustion (self-ignition) of oily waste in an engineer's supply locker over a desk in a boiler room.

Fire from the exhaust of an automobile caused the ignition of gasoline issuing from a leaky connection in a pipe leading to the engine.

Employees were repairing a leaky connection of a gasoline tank in an automobile and seemingly struck a spark or crossed wires with the tools they were using so that the gasoline vapor was ignited.

An employee brought an open pail of gasoline into a shop. The pail was set down near an emery wheel which was being used. A spark from the emery wheel ignited the gasoline.

Three men were tapping a hole in the end of a tank containing gasoline vapor under slight pressure. An electrically driven drill was used in the work. One hole had been drilled into the tank allowing some gasoline vapor to come out. As soon as a second hole was started the gasoline vapor was ignited by the arc between the brush and the commutator of the motor attached to the drill. The three men were severely burned by the explosion that followed.

Employees in a garage had just received a barrel of very light casing-head gasoline. When the bung was opened an enormous volume of gas rushed out under considerable pressure. Attempt was being made to replace the plug in the bung when the gas in the room exploded with great violence.

Horses hauling a tank wagon full of gasoline ran away on the main street of a small town. The wagon upset, spilling the gasoline, which flowed along the street and into a blacksmith shop where there was a lighted fire. The gasoline caught fire and flashed back to the overturned tank wagon which in turn caught fire and caused the death of several persons who had gathered around it.

ASPHYXIATION BY EXHAUST GASES OF AUTOMOBILE ENGINES.

Several people have recently met death by breathing air polluted with the exhaust gases of automobile engines.

In one instance a man went to his garage and started his engine. After he had been away an undue length of time his absence was noted. Upon investigation he was found dead on the floor of the garage. The engine of his automobile was running and the room, which was small, was filled with fumes from the engine exhaust.

Another man met death in substantially the same manner. He went to his garage to warm up the engine of his automobile. Two hours later his body was found in the garage beside the automobile. The engine was running.

A man and his wife were found dead in their garage. The woman was sitting in the automobile and the man was leaning over the door of the machine.

These accidents can undoubtedly be traced to poor combustion and the presence of carbon monoxide, a poisonous gas, in the exhaust gases. Carbon monoxide is formed when gasoline vapor, or any other fuel, is burned without enough air (oxygen) for complete combustion. As little as 0.05 per cent of it in air causes slight symptoms of poisoning after several hours' time. An exposure for as short a time as 20 minutes to air containing 0.20 per cent of it will make most people very sick for hours. One per cent of it in air will cause death in a few minutes.

Tests by the author showed that the explosion of mixtures of gasoline vapor and air produced proportions of carbon monoxide ranging from 0 to 14 per cent.[a] No carbon monoxide was formed when lean mixtures were fired; that is, when sufficient air was present to completely burn the vapor.

Other tests by the Bureau of Mines[b] have shown that carbon monoxide may be produced by an internal-combustion engine using gasoline at rates varying from 10 to 35 cubic feet per minute.

From the foregoing it is clear that people should be very careful in running automobile engines in a garage, especially with rich mixtures. These mixtures often result in the formation of a foul-smelling or smoky exhaust. The effects of poisoning may be nothing worse than a bad headache but may be much more serious.

Garages should preferably be large and well ventilated, and when the engine is running in the garage it is best to have the automobile standing close to wide-open doors. By no means should an engine be run so as to produce a smoky or bad-smelling exhaust in a small garage.

GASOLINE FIRES CAUSED BY FILTERING GASOLINE THROUGH CHAMOIS SKIN.

The National Fire Protection Association[c] reports the results of an investigation of a gasoline fire. A car was being filled with gasoline, which was poured into a funnel through a chamois-skin strainer from a 5-gallon can. As the funnel would not sit upright in the hole of the tank a wooden ring was first placed in the filler hole and the funnel set in that. In this way the wood insulated the funnel from the metal of the tank. After pouring some gasoline through the chamois skin the man brought the pouring can near to the metal edge of the funnel and a spark jumped from the car to the funnel, igniting the gasoline vapor. The prompt use of extinguishers saved the car from serious damage. The man insisted that he heard the spark. It was then decided to try to duplicate these conditions and to make several tests. Gasoline was poured through a chamois-skin-covered funnel insulated from the floor of the garage, and a spark was obtained. In several experiments a gold-leaf electroscope showed a considerable charge of static electricity. The funnel, which was painted on the outside, was placed in the tank of the car without the wooden block, and the experiment was repeated. The size of the charge was considerably less, and when the paint was removed so that the funnel made a good contact with the metal of the tank the electroscope did not show any static charge present.

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[a] Burrell, G. A., and Boyd, H. T., Inflammability of mixtures of gasoline vapor and air, Tech. Paper 115, Bureau of Mines, 1915, 18 pp.

[b] Hood, O. P., and Kudlich, R. H., Gasoline locomotives in relation to safety and health, with a chapter on methods of analyzing exhaust gases by G. A. Burrell. Bull. 74, Bureau of Mines, 1915, 83 pp.

[c] Gasoline fires caused by frictional electricity. Nat. Fire Prot. Assn. Quart., vol. 8, October, 1914, p. 152.

Various other tests convinced those present that gasoline poured through a nonconductor of electricity generates frictional electricity and, as the chamois skin was such a nonconductor, electricity was generated by pouring the gasoline through the chamois. This phenomenon is not new, for an electric spark has been obtained numberless times by friction or by rubbing together two nonconductors of electricity. Gasoline, unlike water, is a nonconductor of electricity.

If the nonconductor is in contact with the ground or a large metallic body, the static electricity generated will be absorbed and will not make its presence known. However, if the nonconductor is in contact with only a small amount of metal, as a funnel or a faucet, this metal becomes highly charged with electricity and will discharge with a good-sized spark if another metallic substance is brought in contact with it or very close to it. Consequently, in the experiments mentioned the funnel, when insulated by the wooden block, became charged and when the metal pouring can was brought near it it discharged a spark of sufficient intensity to ignite the gasoline vapor.

There are other cases on record in which electric sparks have caused fires when gasoline was being filtered through chamois into a tank.

EXTINGUISHING LIQUID FIRES.

There are two principal methods of extinguishing burning liquids, as follows: To form a blanket of gas or solid material over the burning liquid and so cut off the air (oxygen) supply; and to dilute the burning liquid with a noninflammable extinguishing agent that will mix with it.

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Water may be used if the burning liquid is miscible with it. Such miscible liquids include denatured alcohol, wood alcohol, and acetone. When the liquid, like gasoline, is not miscible with water, little or no effect is produced by using water, except to wash the burning liquid out of the building, and thus scatter the fire over a larger area. But in extinguishing a small amount of burning oil, a large quantity of water may aid by its cooling effect.

Of those materials used for extinguishing liquid fires by forming a blanket of gas or solid material over the burning liquid, thus cutting off the oxygen supply, several are in common use. These include sawdust, sand, carbon tetrachloride, and the so-called foamy or frothy mixtures.

Sawdust floats for a time on the liquid and excludes the oxygen of the air. Sawdust itself is not easily ignitible. The character of the sawdust and its moisture content are of little or no importance. For putting out small or incipient fires long-handled wooden shovels are a convenient means of handling the sawdust.

Sand proves about as efficient as sawdust for extinguishing fires on the ground, but is heavier and more awkward to handle. When thrown on a burning tank, it sinks, whereas sawdust floats.

Carbon tetrachloride is the basis of "pyrene" and other ready fire extinguishers; if thrown on a fire it forms a heavy noninflammable vapor, about five times as heavy as air, over the liquid. Its specific gravity is 1.632 at 32° F. It mixes readily with oils, waxes, and japan. Much carbon tetrachloride contains impurities that give it a bad odor. When carbon tetrachloride is thrown on a fire black smoke is produced, which is undoubtedly finely divided carbon. Pungent gases, probably hydrochloric acid gas and small amounts of chlorine gas, are also produced, but brief exposure to them does not produce permanent injury.

The extinguishing effect of carbon tetrachloride depends greatly on the skill of the operator. If liquid in a tank is on fire, the height of the liquid is important. When the liquid is low, the sides of the tank form a pocket which retains the vapor, but when a tank is nearly full of a highly volatile liquid like gasoline, only the most skilled operator can extinguish a fire in it.

USE OF FOAM OR A FROTHY MIXTURE.

Equipment for using foam or frothy mixtures to extinguish fires in large gasoline storage plants originated in Germany. The process consists in causing two liquids to mix, whereupon foam is produced, which is forced out by the pressure of carbon dioxide gas simultaneously generated, and acts as a blanket in excluding air (oxygen) from the fire. The foam is tough and shrinks only slightly in volume even after half an hour.[a]

The National Fire Protection Association has experimented with this and other methods of extinguishing fire.

In some large plants gasoline is continually stored under the pressure of a noninflammable gas, as nitrogen or carbon dioxide. In some other plants it is stored in a tank, which is always kept filled, no air being admitted at any time. The tank may be filled with all gasoline or part gasoline and part water, water being pumped into the tank to force out the gasoline, when it is desired. The water may be drained off when more gasoline is to be added to the tank.

SUMMARY.

During 1913, in the United States, 1,040 persons were burned to death and 3,120 persons injured through gasoline fires.

At ordinary temperatures air will hold from about 5 to 28 per cent of gasoline vapor.

The limits of explosibility are between about 1.5 per cent and 6 per cent of gasoline vapor. In other words, only a little gasoline vapor is needed to render air explosive—1½ cubic feet of vapor for each 97½ cubic feet of air.

One gallon of gasoline can, under perfect conditions, render 2,100 cubic feet of air explosive.

The vapor from gasoline is especially dangerous, in that after it is given off from the gasoline it may travel a considerable distance from the gasoline and there be ignited, the flash traveling back to the container and causing a roaring fire in a few seconds.

Gasoline vapor is about three times as heavy as air, hence in mixing with the air after having been given off from the liquid, it is found in largest proportion near the floor.

In using gasoline, observe the following precautions:

Handle no more than the smallest amount needed for doing the work.

Do not allow open lights, flames of any kind, or machines or belts capable of producing a spark in a room where gasoline is used. Use incandescent lights provided with guards.

Place all electric switches and fuses outside the room.

Post danger signs.

Store large quantities of gasoline in a metal tank buried outdoors and at a safe distance from other buildings.

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[a] In one type of equipment water, bicarbonate of soda, soap and bark are used in one tank and acid in another tank. A fusible link that melts at 212° F. releases a hammer, which breaks glass in a tank containing the acid. In other types of equipment two solutions somewhat similar to the above are contained in separate tanks and are pumped at the first indication of a fire through two pipes into a common pipe from which they are discharged onto the tank that is on fire. Some large refineries are equipped to handle the solutions in this manner.

Pump as much gasoline as is needed into the building at one time, but no more.

When the use of an open can is necessary, see that the opening is as small as possible and that a cover is provided.

Store empty gasoline barrels with bung holes down in a safe place in the open air.

Keep the doors of rooms where explosive or dangerous gases or vapors are used or generated tightly closed and provide effective ventilation.

Keep tight the joints of tanks, pipes, and conveyors used in storing explosive liquids, gases, or vapors.

Before doing work on vessels, pipes, etc., wait long enough for any gas to escape from them.

Take especial care before doing work that requires the use of heat or flame. Apparatus that has contained explosive gas should be filled with water or steam to force out the gas.

Do not spill gasoline.

Always put oily waste in a safe receptacle, to prevent spontaneous ignition.

Kerosene should never be poured into a stove in which there is a spark of fire, nor when the fire is out but the stove is still warm.

Neither should kerosene lamps be filled while lighted.

Do not fill the tank of the stove full.

Do not use a stove that leaks.

Do not fill a gasoline stove in a closed room. Have plenty of ventilation to carry the vapor out of the room.

Do not use gasoline or naphtha for washing the hands.

As the exhaust gases from automobiles may contain deadly proportions of carbon monoxide, do not run automobile engines on rich mixtures in small or closed garages.

Under certain conditions electric sparks can be produced in pouring gasoline through chamois skin.

Water thrown onto a gasoline fire does not mix with the gasoline but only spreads the burning liquid, and thus scatters the fire over a larger area. But if the amount of burning oil is small a large quantity of water may do something because of its cooling effect.

Sawdust, sand, and carbon tetrachloride are especially useful for putting out gasoline fires. Small fires may be extinguished sometimes by smothering them with a blanket.

PUBLICATIONS ON PETROLEUM TECHNOLOGY.

A limited supply of the following publications of the Bureau of Mines has been printed and is available for free distribution until the edition is exhausted. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

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